

ENGINEERING WITH NATURE: NEARSHORE BERM PLACEMENTS AT FORT MYERS BEACH AND PERDIDO KEY, FLORIDA, USA

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Abstract: Two nearshore berm nourishments were placed at Fort Myers Beach and Perdido Key Florida, USA, as part of Regional Sediment Management practices. At Fort Myers Beach, a bar-like berm was placed offshore, while at Perdido Key a “swash-zone berm” was placed approximately half-way between the mean water line and berm crest to maximize the potential for mobilization. The morphologic and sedimentologic evolution of both study areas was documented based on beach profile surveys and sediment sampling. Both projects were successful in that they added sediment to the littoral system and dry beach, protected the natural beach from storm impacts, and equilibrated with the natural system making the placement site sustainable for future projects. The nearshore berm at Fort Myers Beach contained mixed sediment and fine material initially located in the trough landward of the berm migrated offshore, while coarser beach quality sediment moved onshore. Sediment at Perdido Key was beach-quality sand slightly finer than the native sand on the subaerial beach, and was successfully integrated over the two-year monitoring period.

Introduction

Navigation channels at inlets are often dredged to maintain safe navigable depths. As part of Regional Sediment Management and Engineering with Nature practices, strategic placement in the form of nearshore feeder berms seeks to maximize benefits to the environment and minimize negative impacts from finer non-native material by placing sediments in such a way that natural processes selectively sort fines from coarser sediments, and move beach-quality sand onshore and finer fractions offshore.

Two nearshore feeder berm placements were constructed at Fort Myers Beach and Perdido Key, Florida, USA in 2009 and 2012, respectively. Both were maintenance dredging projects from nearby inlet navigation channels. The Fort Myers Beach project was built as a submerged nearshore berm at approximately -2 m relative to North Atlantic Vertical Datum 1988 (NAVD88), while Perdido

Key was a swash-zone berm, built at approximately half-way between the mean water line and natural berm crest at +0.91 m NAVD88. At this location, 0 m NAVD88 is roughly 0.09 m below mean sea level. The Fort Myers Beach nearshore berm consisted of mixed sediments with up to 16% fines defined as grains finer than 0.063 mm. The intent was to build the berm in such a way that the fine sediment would transport and deposit offshore, while relatively coarse beach quality sediment would move onshore and potentially nourish the leeward beach. The swash-zone berm at Perdido Key was designed to rapidly mobilize sediment to nourish nearby beaches.

Study Areas

Fort Myers Beach is located on Estero Island, a heavily developed island in west-central Florida (Figure 1). The area experiences relatively low wave energy, with the exception of cold fronts and tropical systems. On average, wave heights during the study period were 0.16 m with spring and neap tides of 1.2 m and 0.75 m, respectively (Brutsché et al, 2014a). Matanzas Pass is a federally maintained channel located at the north tip of the island and is used for recreation as well as passage for the U.S. Coast Guard station. The channel has been dredged to maintain navigable depths several times since its construction in 1961. In 2009, the channel was dredged, and mixed sand and silt-sized sediment was placed in the nearshore in the form of an elongate berm. The berm shape was not uniform alongshore, and was much larger than the natural bar that typically exists in the area. Due to the placement techniques, several gaps approximately 15 m wide were created in the berm. The berm was approximately 1.6 km long, 120 m wide and 1 m high for a total volume of nearly 175,000 m³.

Perdido Key is a barrier island in the northwest panhandle portion of Florida (Figure 1). The study area was on the eastern portion of the island, immediately adjacent to Pensacola Pass, and completely within the Gulf Islands National Seashore. Unlike Fort Myers Beach on Estero Island, the Perdido Key study area is virtually undeveloped, with the exception of park structures. This study area experiences low to moderate wave energy, except during winter cold fronts and tropical storms. Average wave height measured during the study period was approximately 0.64 m. Tides are diurnal with spring tidal range up to 0.6 m, and neap tidal range of 0.18 m (Brutsché et al., 2014b). Pensacola Pass is often dredged to maintain navigable depths. Prior to 1989, 75% of the sediment dredged from the pass, primarily sand, was placed offshore and out of the littoral zone (Browder and Dean, 2000; Brutsché et al., 2014b). Since then, as part of Regional Sediment Management, sand has been placed both in the nearshore and on the beach. The most recent dredging began in 2011, with sand being placed in the form of a swash-zone berm, not to exceed +0.91 m NAVD88. The

nourishment was approximately 3.2 km long, extending the beach 60 m, for a total volume of approximately 400,000 m³.

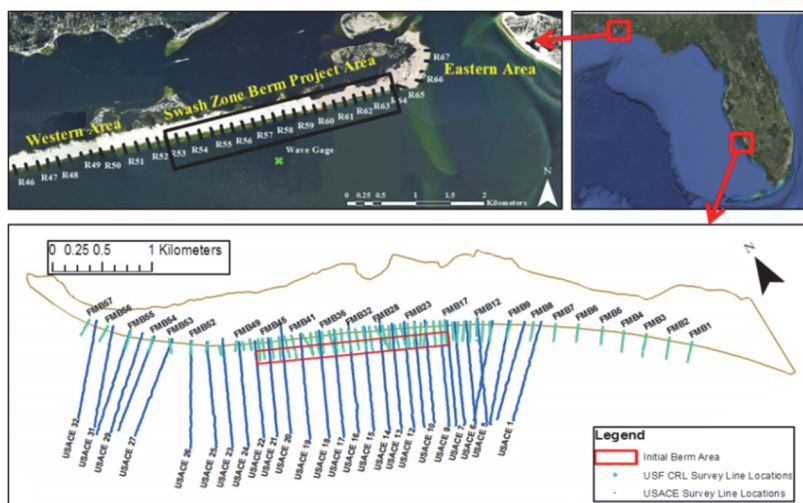


Fig. 1. Locations of study areas. Perdido Key is located on the northern panhandle portion of Florida (upper left), and Fort Myers Beach is located on the west-central portion of Florida (lower), USA.

Methods

The morphological evolution of both of the nearshore placements was studied using time-series beach profile surveys. The study areas were divided into three areas: the project area and control areas on either side. In both cases, the U.S. Army Corps of Engineers (USACE) conducted pre- and post-construction surveys, and all subsequent surveys were conducted by the University of South Florida Coastal Research Laboratory (USF-CRL). USF-CRL surveys were conducted bi-monthly to semi-annually for four years and two years post-placement of the Fort Myers Beach nearshore berm and the Perdido Key swash-zone berm, respectively.

Surface sediment samples were collected at each study site. At Fort Myers Beach, samples were taken in April 2010 and June 2011 to document the evolution of sediment characteristics. In addition to surface sediment samples, vibracores were extracted at Fort Myers Beach in November 2010. Pre- and post-placement samples were taken at Perdido Key to compare the native and nourishment sediment. At each study area, approximately 200 samples were collected and analyzed. Samples were taken along beach-profile transects to analyze the cross-shore variations in sediment characteristics. The Moment

Method (Folk and Ward, 1957) was used to calculate the size and sorting of each of the samples.

Results

The following section summarizes the morphologic and sedimentologic evolution of the two study areas based on the beach-profile surveys and surface (and subsurface, in the case of Fort Myers Beach) sediment samples.

Fort Myers Beach

The pre-placement profile at Fort Myers Beach contained a small natural bar, generally 0.5 m high, located approximately 50 m offshore of the zero NAVD88 contour (Figure 2). The natural bar was dynamic, as well as ephemeral. The nearshore berm, placed in May 2009, was much larger than the natural bar. Generally, the berm was approximately 1 m high, 100 m wide, and placed approximately 120 m offshore of the zero NAVD88 line. During the first two years post-placement, the berm migrated onshore continuously. The survey conducted approximately 1 year after placement (April 2010 survey) showed an onshore migration of approximately 50 m. From April 2010 to October 2010, the berm only moved onshore 25 m or less. However, during the next 8 months including the winter, the rate of onshore migration increased (up to 50 m between due to the higher energy wave conditions caused by cold front passages). Onshore migration continued during the 2011 summer months, for a total of just less than 100 m of onshore migration of the berm within the first two years following placement. The dry beach remained relatively stable during this time.

During the third year post-placement, Tropical Storm Debby (late June 2012) and Hurricane Isaac (late August 2012) impacted the study area. Tropical Storm Debby “split” the berm into two smaller bars (Figure 3; 0712 survey), however, the features remained generally in the same place as the larger berm. No significant erosion occurred on the dry beach. The two bar morphology remained after Hurricane Isaac, however the inshore bar moved onshore, and the offshore bar moved offshore. It is important to note that during both storms, the control areas experienced much more erosion of the dry beach than the berm project area dry beach (Figure 4). By May 2013 (four years post-placement), the shape of the berm project area profiles resembled the pre-placement shape, however, the entire profile was shifted seaward. All profiles experienced a gain of sediment on the dry beach in terms of width and volume. In this study (Figure 3), the dry beach gained approximately 15 m of width.

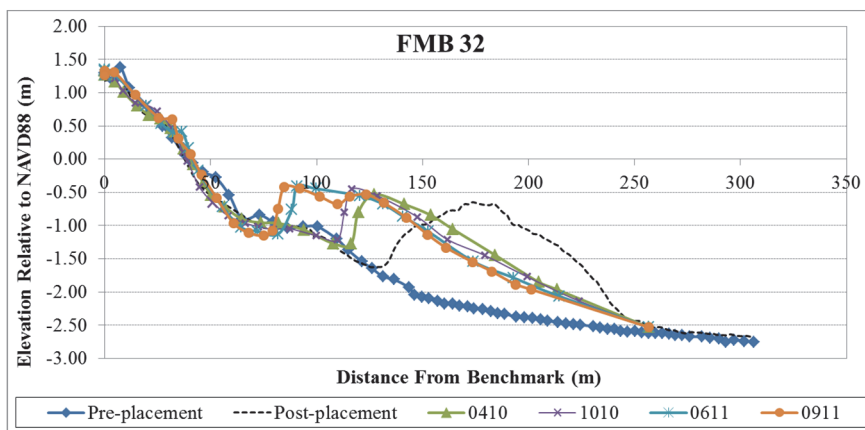


Fig. 2. Time series profile in the berm project area at Fort Myers Beach for the first two years post-placement (modified from Brutsché et al., 2014a).

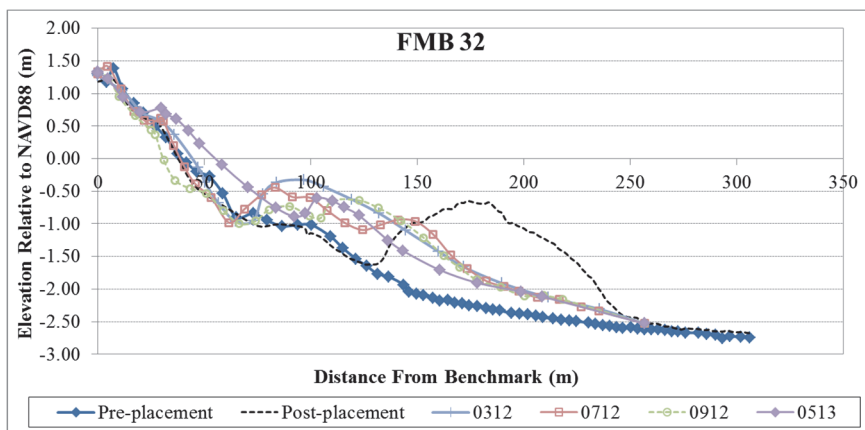


Fig. 3. Time-series profile in the berm project area at Fort Myers Beach 3 and 4 years post-placement (modified from Brutsché et al., 2014a).

Grain size of surface sediment taken from within the project area from April 2010 and June 2011, as well as grain sizes corresponding to samples from vibracores extracted in November 2010 are illustrated in Figure 5. The finest sediment was initially found in the trough landward of the berm. However, by June 2011, sediment in the berm crest and offshore was finer than the trough. The dry beach remained rather constant in terms of sand size over the two years, indicating that the fine material initially found in the trough landward of the berm moved offshore, rather than onshore.

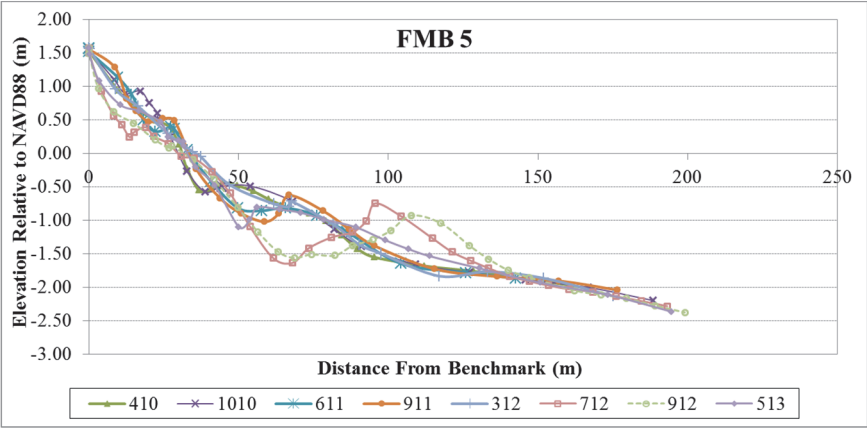


Fig. 4. Time-series beach profile surveys at a profile in the control area of Fort Myers Beach.

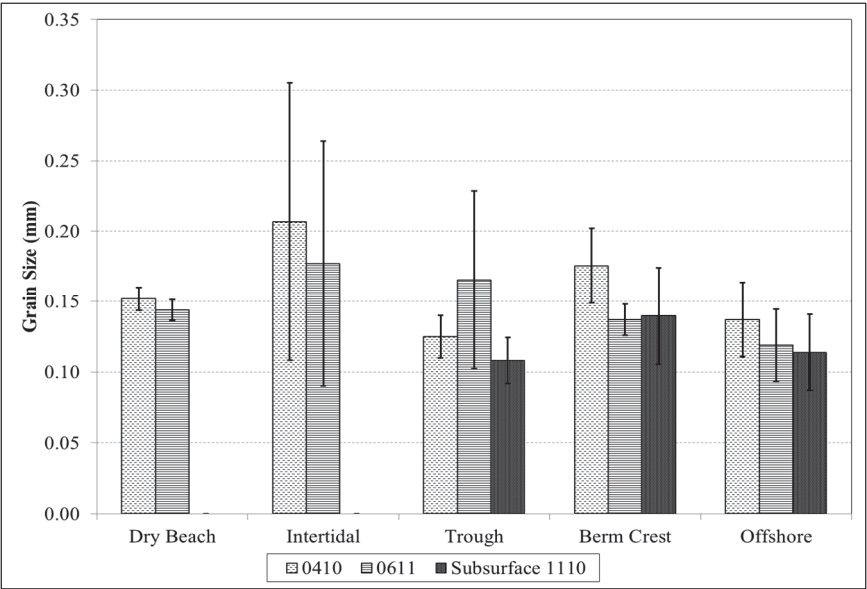


Fig. 5. Cross-shore and subsurface sediment distribution of samples taken at Fort Myers Beach (modified from Brutsché et al., 2014a).

Perdido Key

At Perdido Key, the pre-placement profile contained a natural beach and berm crest elevation of approximately +2.0 m NAVD88 and a steep foreshore slope (Figure 6). A bar existed 50 m offshore, with elevation near -1 m NAVD88, and

width near 10 m. The nourishment was placed with a berm elevation of +0.91 m NAVD88, extending, on average, 60 m seaward from the foreshore slope. The nourishment was designed to rapidly mobilize sediment in hopes that it would quickly nourish downdrift beaches, both in the nearshore and the dry beach. Within the first two months following placement, the nourishment eroded rapidly, losing approximately 25 m in width. The active berm crest began to increase in elevation as sediment eroded from the foreshore, and was deposited on the berm crest. Tropical Storm Debby in July 2012 led to more erosion of the nourishment, and the formation of a large storm berm (approximately 1 m high and 25 m wide) depositing on the beach, up to the +2.0 m NAVD88 contour. Hurricane Isaac in September 2012 led to more erosion and subsequent deposition on the dry beach. Through this process, by July 2013, the profile had returned to the pre-placement shape profile, with the beach at the +2.0 m NAVD88 contour, steep foreshore slope, and offshore bar. Some of the sediment not accounted for on the dry beach of the project area could be seen in the nearshore of the adjacent control area profiles (Figure 7).

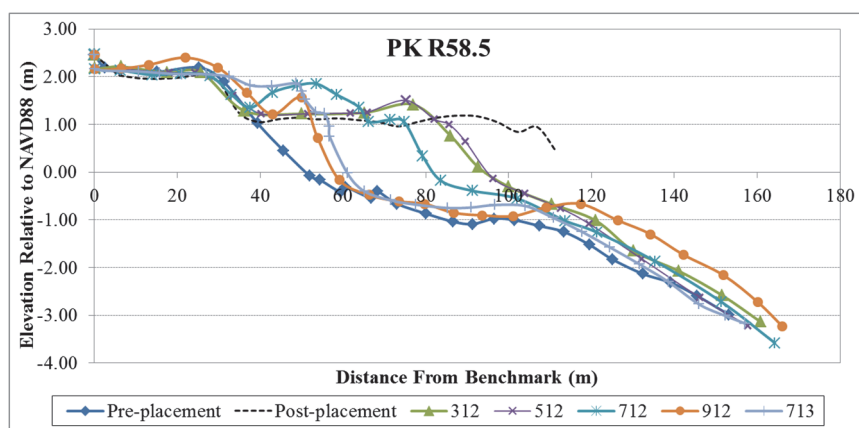


Fig 6. Time series beach profiles at Perdido Key (modified from Brutsché et al., 2014b).

Sediment samples were collected at the study area pre- and post-placement of the swash-zone berm. The average pre-placement dry beach sediment grain size was 0.40 mm, and post-placement berm sediment was 0.34 mm, or approximately 15% finer (Brutsché et al, 2014b). The beach sediment showed an eastward decreasing trend before the nourishment, while sediment grain size became more uniform alongshore after the nourishment.

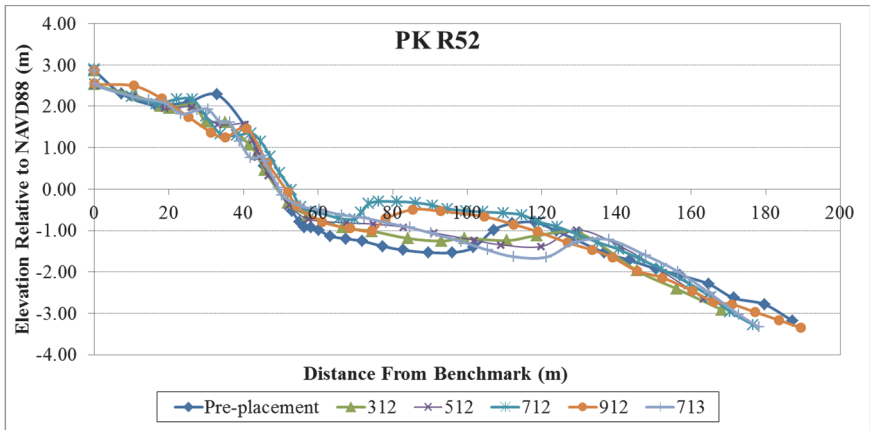


Fig. 7. Time-series beach profile surveys at the control area (west of project area) at Perdido Key (modified from Brutsché et al., 2014b).

Discussion

Sustainability of the Placement Site

Often it is the goal of Regional Sediment Management projects to design the placement in such a way that sediment will transport outside of the placement site, so that the site may be used again in the future. In other words, the site will return to its pre-construction shape, defined here as its equilibrium shape, so that the site may be reused for future nearshore placement projects. Figures 8 and 9 illustrate the average variance from the average profile calculated for Fort Myers Beach and Perdido Key, respectively. Detailed information on the calculations used to create these figures can be found in Brutsché et al. (2014a) and Brutsché et al. (2014b). Large variances from the average profile (representing the equilibrium state) indicate that the profiles at that particular time deviated substantially from the equilibrium profile, while small variances suggest that the profile at that particular time is close to its equilibrium state.

In the case of Fort Myers Beach (Figure 8), the pre-construction variance in both the berm project area lines and the control area lines were quite similar. Prior to Tropical Storm Debby and Hurricane Isaac, the average variance of the control area lines remained rather stable through time. After the two storms, there was an increase in the variance as the control profiles formed a large bar offshore, but it quickly decreased as the profiles recovered. In the berm project area, as expected, the immediate post-placement survey showed a large increase in the average variance of the profiles from the average profile. This number generally decreased through time, however, the rates of decrease gradually slowed until the passage of Tropical Storm Debby and Hurricane Isaac. A slight deviation

from the overall trend was seen following the passage of the two storms, however, following Isaac, the variance rapidly decreased to approximately the pre-construction variance in the berm project area, indicating that the berm had equilibrated, and that the storms may have accelerated the process. In other words, the profiles had returned to a shape similar to that of the average (or equilibrium) profile for the study area. Because the large berm no longer exists in the original placement site, as indicated by both the time-series beach profile surveys and the variance from the average profile, it is evident that it can be used once again for strategic placement of dredged sediments, making it a sustainable site. However, consideration must be given to the offshore shift of the profile, as it may impact the cross-shore location of future placements.

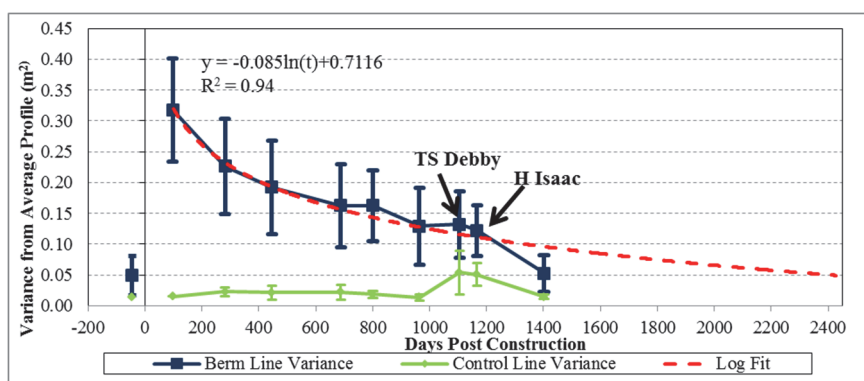


Fig. 8. Average variance from the average profile at Fort Myers Beach (from Brutsché et al, 2014a).

A similar exercise was conducted at Perdido Key, although with different resulting trends (Figure 9). In this case, variances in the berm project area were similar to the adjacent area during the pre-construction period, and then increased after construction. However, rather than a continual decrease in variance as observed at Perdido Key, there was a slight increase in variance prior to the passage of Tropical Storm Debby. Similarly, the passages of the two storms led to a rapid decrease of variance, even exhibiting a smaller variance than the adjacent area variance following the passage of Hurricane Isaac. As the profiles recovered from the storms, the adjacent area lines and berm project area lines slightly increased to the same variance, which is approximately the same as the pre-construction variance. By examining Figure 9 and the shape of the final survey profile in Figure 6, it is evident that Perdido Key has also equilibrated, with most of the nourishment sediment being transported out of the placement site, allowing the area to be used for future Regional Sediment Management projects.

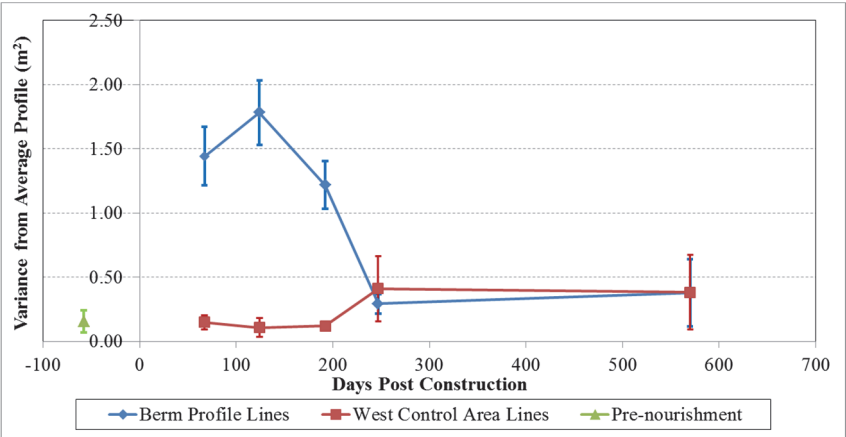


Fig. 9. Average variance from the average profile at Perdido Key (from Brutsché et al, 2014b).

Benefits from the Strategic Placements

One of the over-arching goals of Regional Sediment Management and Engineering with Nature is to maximize benefits while also minimizing negative impacts to the placement site and surrounding areas. At Fort Myers Beach, all but one of the profiles within the berm project area gained both dry beach width and volume over the course of the study (Figure 10). The dry beach gained up to 25 m in terms of width. Total volume gain on the dry beach was approximately 17,500 m³ or 10% of the total volume of the initially placed berm. It is unclear whether the sediment gained on the beach was due to a net onshore sand transport from the nearshore berm or from the impoundment of longshore sediment transport due to the fact that waves were breaking over the nearshore berm rather than at the shoreline, i.e., the berm functioned as a breakwater. The overall gain of sediment on the dry beach in the berm project area as well as the time-series beach profile surveys also show that the nearshore berm provided some storm protection during Tropical Storm Debby and Hurricane Isaac.

Important to note is that while the berm project area gained a significant amount of sediment on the dry beach, this increase was not at the expense of the surrounding beaches. In fact, profile lines immediately adjacent to the southeast portion of the berm gained sediment on the dry beach as well, up to approximately 15 m in width, and 5 m³/m in volume. Even the more distant control profile lines gained sediment on the dry beach. These data indicate that although this particular placement was built in a similar shape as a submerged breakwater, it did not create negative impacts to adjacent beaches caused by wave refraction around the ends of the placement.

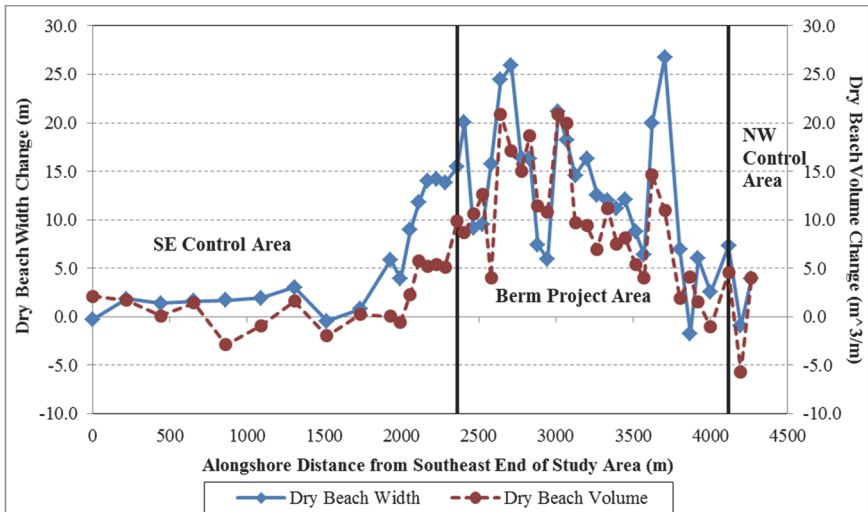


Fig. 10. Dry beach width and volume changes at Fort Myers Beach (from Brutsché et al., 2014a).

At Perdido Key, benefits were measured differently. In this case, volume gain above the +0.91 m NAVD88 contour was considered as positive impact to the dry beach by onshore movement of the berm sediment. Figure 11 summarizes the volume and width gain of the +0.91 m NAVD88 contour at Perdido Key. Contour width decreased throughout most of the study period, however, on average, 7 m remained after the first 18 months following placement. Additionally, just over 10,000 m³ was gained on the beach over the study period. However, similar to the case at Fort Myers Beach, at its peak, approximately 10% of the original placed volume was accounted for on above the +0.91 m NAVD88 contour. At this study area, both Tropical Storm Debby and Hurricane Isaac had substantial impacts, causing a significant amount of beach erosion. Additionally, some overwash occurred, and may have carried sediment past the landward extent of the profile lines. Regardless, even with the passage of both storms, all of the profiles in the study area had more sediment above the +0.91 m NAVD88 contour than at the beginning of the study, which implies that the nourishment provided storm protection.

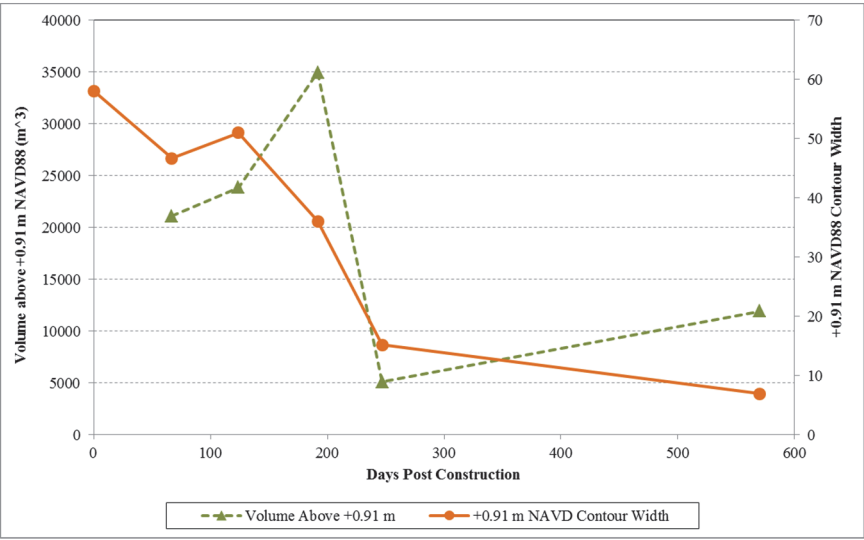


Fig. 11. Dry beach width and volume changes at Perdido Key (from Brutsché et al., 2014b).

Use of Mixed Sediment

The potential use of mixed sediments in strategic placement projects is another practice of Regional Sediment Management and Engineering with Nature. The goal is to place material in such a way that fine sediment may be winnowed from the placement sediment and ideally move offshore. In the case of Fort Myers Beach, this design proved to be successful. The construction of the berm left fine sediment in the relatively low energy trough area landward of the berm, which was subsequently transported and deposited offshore through surf zone processes. Strategic placement within the active surf zone maximized the benefit of using initially non-beach quality material. Natural processes moved coarser beach quality material onshore, and transported finer sediments offshore, keeping the dry beach sediment consistent with pre-placement conditions, a good environmental and recreational outcome. Gaps initially constructed in the berm may have aided in the offshore transport of the fine material. The success of this study indicates that this site could be used for placement of mixed sediment material and subsequent dredging of material once the undesirable fine fraction has winnowed out.

Conclusions

Although quite different designs, both the Fort Myers Beach and Perdido Key Regional Sediment Management projects can be considered successes in maximizing benefits to the beach-nearshore environment while minimizing

negative impacts. Both projects added sediment to the littoral system, a portion of which was deposited on the dry beach, as well as acted to provide storm protection. Additionally, beach profiles within both project areas returned to their pre-placement equilibrium shapes, allowing for future projects to be constructed in the same place. Finally, the nearshore berm at Fort Myers Beach showed the potential in placing mixed sediment in the nearshore without negative impacts on the beach and surrounding environment. For these reasons, both study areas can be considered successful examples of Regional Sediment Management and Engineering with Nature.

Acknowledgements

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